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Integrated electrical-mechanical analysis - The impact of power system on wind turbine design and vice versa

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Integrated electrical-mechanical analysis — The impact of power system on wind turbine design and vice versa

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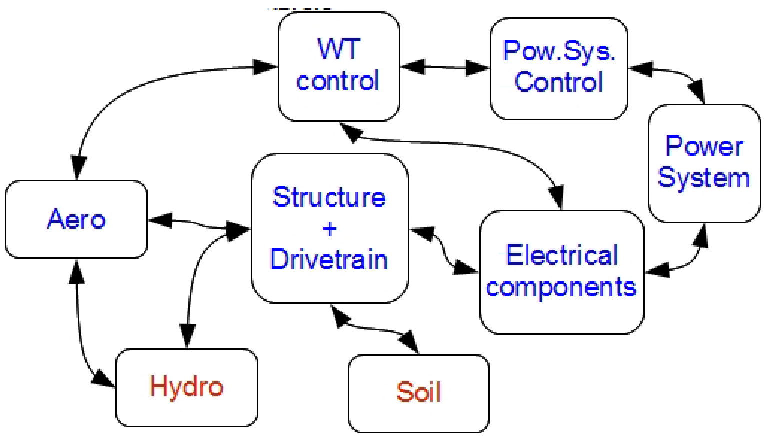
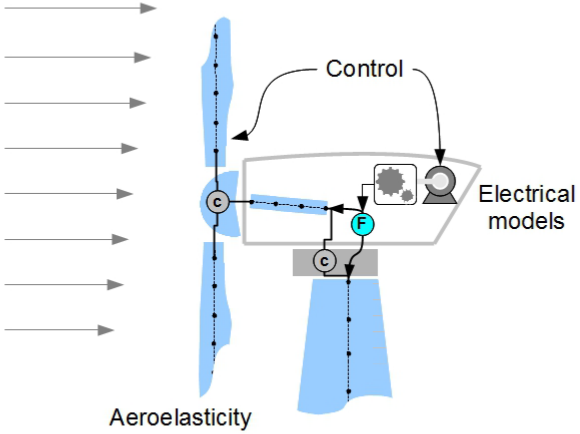
Outline

- **Introduction**
  - Motivation
  - Conceptual frame work for integrated design
  - Simulation environment for electrical-mechanical integrated analysis
- **Application examples**
  - Vibrations due to unbalance voltage
  - Wind turbines providing inertial response
- **Conclusions and Future work**

Motivation and background

- The need for integrated design
  - Lower cost of energy
  - Higher reliability
  - Better integration to the power system
- The role of integrated dynamic analysis
  - Verification of static design
    - Structural
    - Components
    - **Power system requirements**
  - Optimization of designs
    - Development of advanced controls
- Development of simulation tools
  - Extension of simulation domain
  - Interfacing codes for different disciplines
  - Modularity in order to modify sub-models





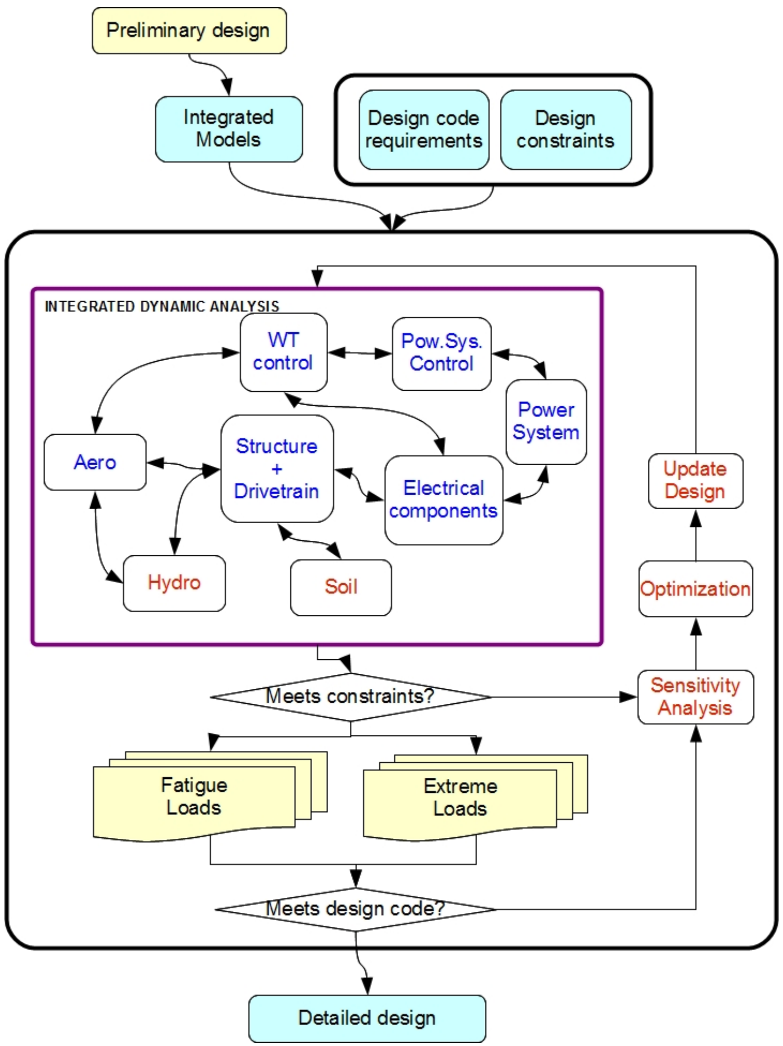
Conceptual framework for integrated design

Departing from …

a. preliminary design, and
b. defined design constraints and requirements

This framework consists in…

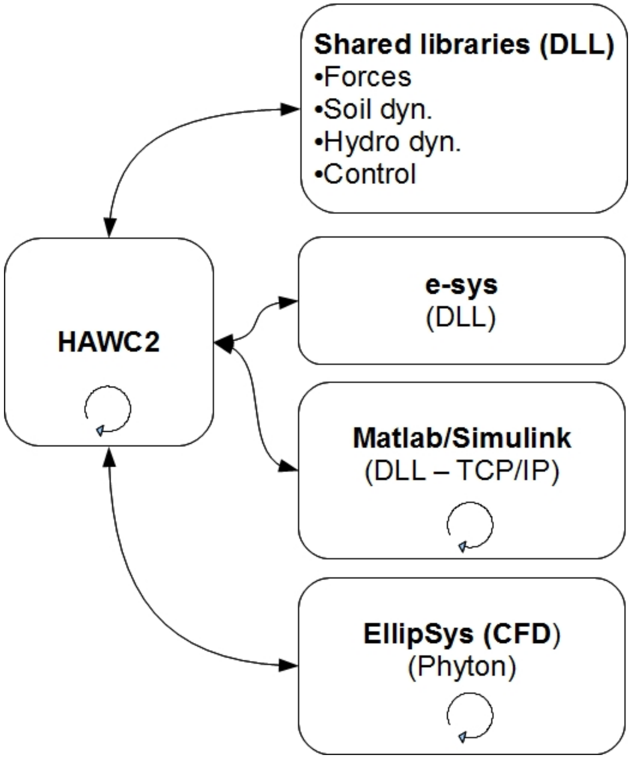
1. Dynamic Analysis
   - Aeroelasticity
   - Electrical
   - Control
2. Optimization
3. Design verification



Simulation possibilities using HAWC2

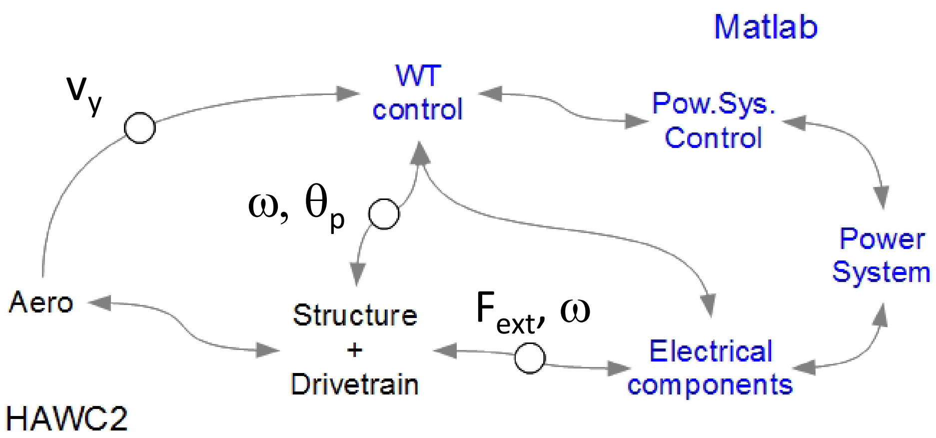
Aeroelastic code HAWC2 -> www.hawc2.dk

- Shared libraries
  - Forces
  - Hydrodynamics and Soil-dynamics
  - Control
- External systems interface
  - Inclusion of any dynamic system
  - One solver: strong coupling, numerical robustnest
- **Co-simulation**
  - Modularity and flexibility
  - Draws on modeling techniques and simulation tools from different fields
    - Circuit theory of electrical machines
    - Multibody dynamics —HAWC2



Simulation environment using HAWC2 and Matlab/Simulink

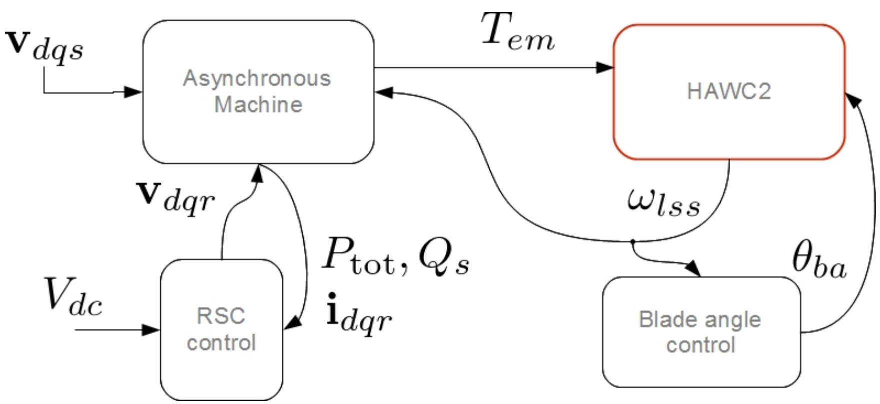
- Software framework
  - Both applications are kept stand-alone
  - Run simultaneously and interact every time-step
- Simulator coupling
  - Non-iterative
  - Matlab/Simulink: variable or fixed time step
  - Applied impact of power system on wind turbine and vice versa



1. Voltage fault analysis
2. Inertial response of wind turbines

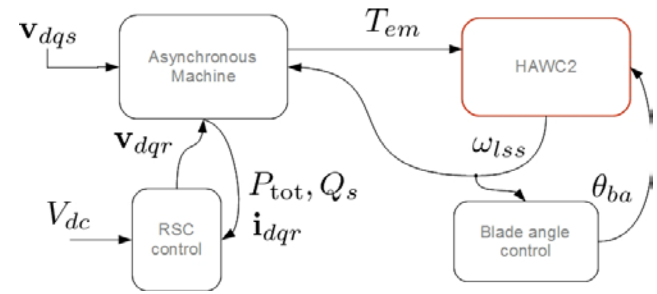
Vibrations in DFIG wind turbine due to unbalance voltage

- Unbalanced faults happen more often than balanced ones
  - Vibrations are hard to control
  - Electrical control design does not consider wind turbine
- Integrated analysis model
  - Aeroelastic model of wind turbine (HAWC2)
  - Pitch control
  - Asynchronous machine + control
    - Rotor and Stator fluxes
    - Current and power control of rotor side converter
    - **Resonant damping control**

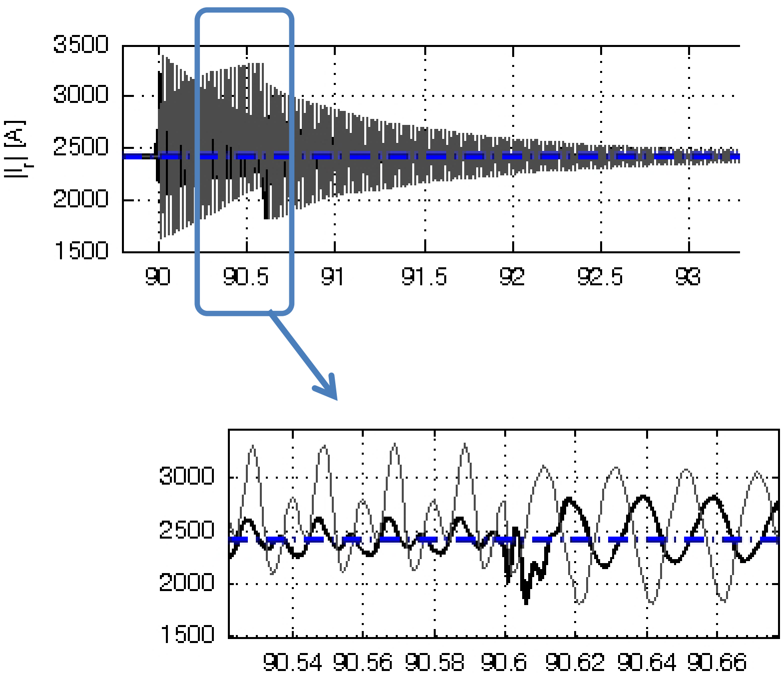


Vibrations in DFIG wind turbine due to unbalance voltage

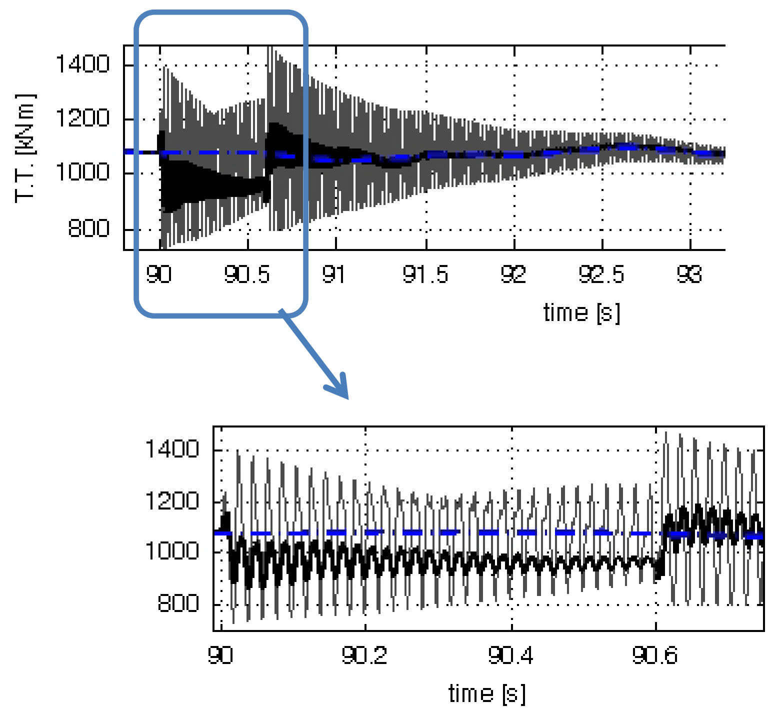
- Resonant damping control (solid black line) reduces electrical and structural loads



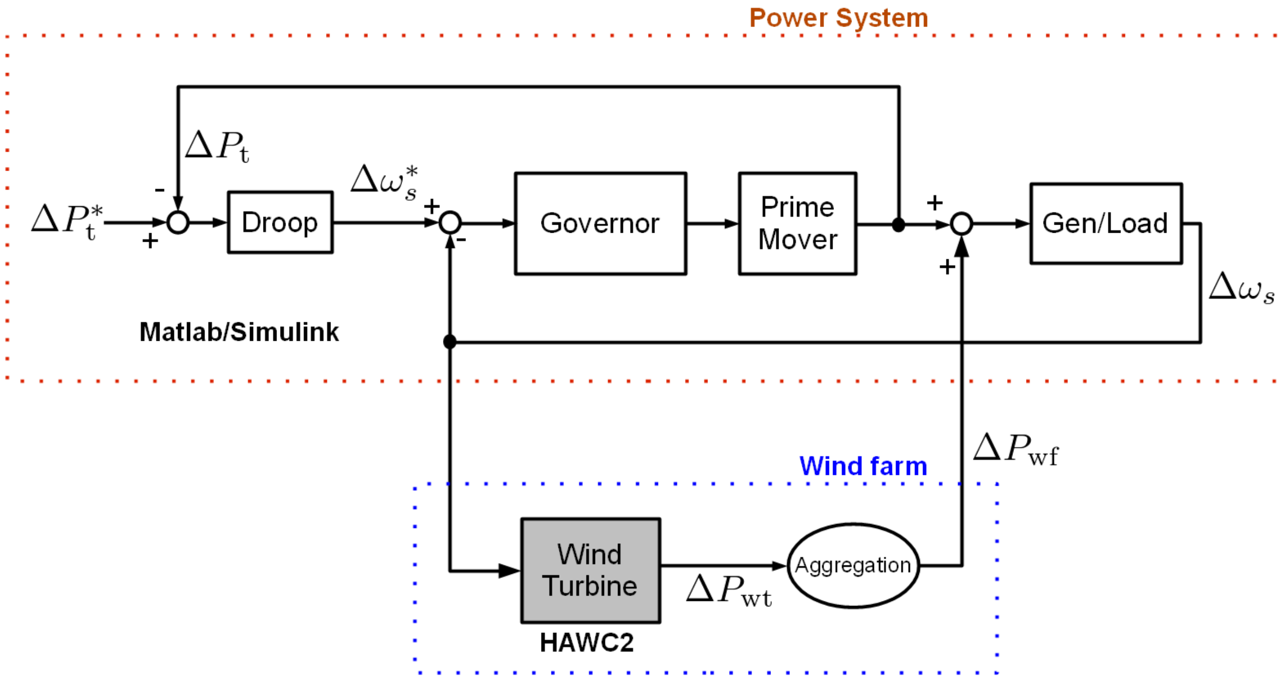
Generator rotor current



Tower top side-to-side moment



Wind turbines providing inertial response



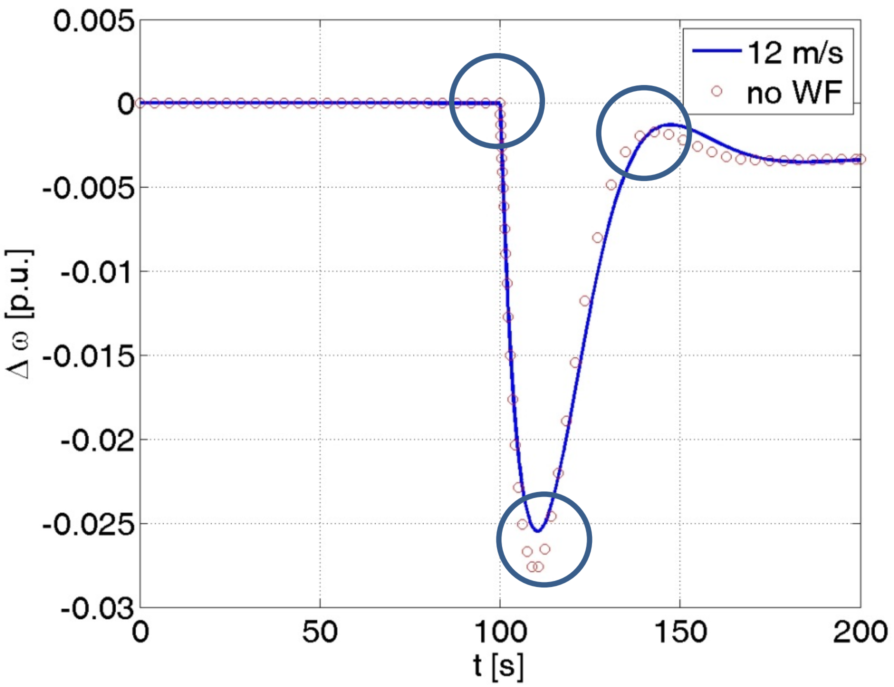
- Lumped power system model
- Aggregated wind farm response
- Wind turbine model
  - Aeroelastic, electrical and control

- Simulation of sudden loss of power
  1. Without wind farm
  2. Wind farm with inertial response producing rated power

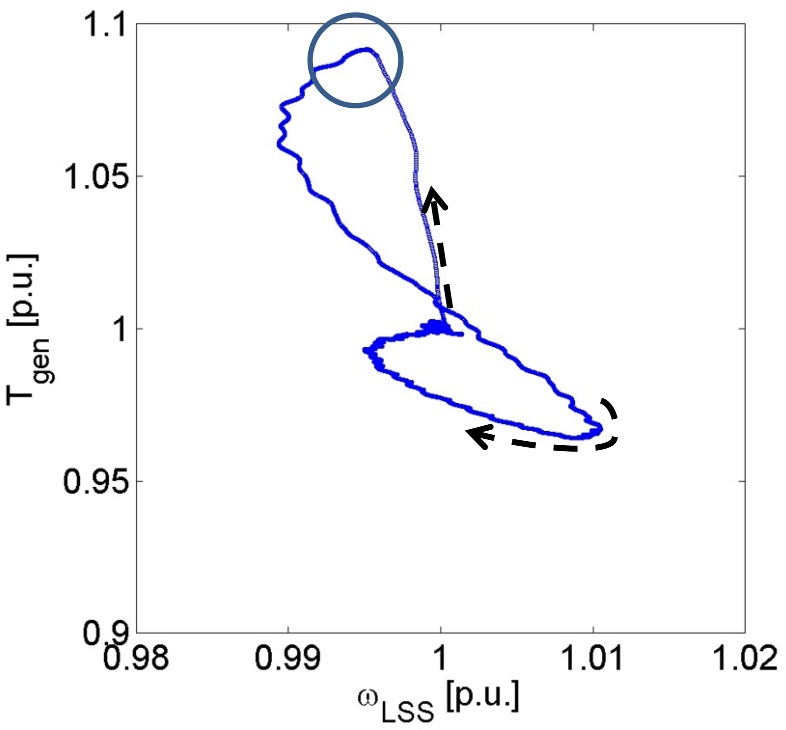
Wind turbines providing inertial response

- Response of wind turbine and power system to a sudden loss of generation

Power system frequency



Wind turbine torque-speed



- Conclusions
  - Power system conditions and requirements can impose loads on components that need to be assessed in order to optimize design
  - Integrated analysis can facilitate the estimation of the impact that of power system requirements have on wind turbine design and vice versa.

- Future work
  - Development of load reduction controls
  - Extension of models
    - drive train
    - bed plate models
  - Validation of models with measurements